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Tying VLBI and GPS Terrestrial Frames: Case Study at Yebes Observatory

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Abstract

Using the estimated coordinates in a common terrestrial frame, we have obtained the relative vector between the reference points of the GPS station and the 14-m and 40-m VLBI radio telescopes at the Yebes observatory. These vectors between both space geodetic instruments is a key issue for the realization of the International Terrestrial Reference Frame. As a preliminary assessment of the local-tie survey, the estimation of the position and velocity in the ITRF2008 is used to derive the relative vector between these three instruments at the Yebes observatory. In the absence of systematic errors in the VLBI, the GPS, and the terrestrial survey observations, local-tie surveys and ITRF-derived relative vectors should agree. From the estimated coordinates of their reference points in the ITRF2008, we discuss the main issues of tying both VLBI and GPS terrestrial frames: how precisely is the relative position of both instruments determined? How does the data analysis and the observation setup impact the ITRF-derived vector?

1. Introduction

Most of the space-based and ground-based Earth observation, such as precisely determining satellite orbits, monitoring Earth rotation, modeling tectonic plate motion, or assessing sea level rise and its variability in space and time, fundamentally depend on the availability of a global Terrestrial Reference System (TRS) that only space geodesy is able to realize [1]. The four space geodetic techniques currently used to realize a geometric Terrestrial Reference Frame (TRF) are: Doppler Orbitography and Radiopositioning Integrated by Satellite (DORIS), Satellite Laser Ranging (SLR), Global Navigation Satellite Systems (GNSS), and Very Long Baseline Interferometry (VLBI). The combination of the TRF of each technique allows the best International Terrestrial Reference Frame (ITRF) realization possible. The ITRF is regularly updated by the International Earth Rotation and Reference Systems Service (IERS) to take into account not only new accumulated data, but also improved data analysis strategies of each technique. The last realization released by the IERS in 2010 has been the ITRF2008 [1] covering a data span from the beginning of space geodesy (∼1980) to 2008.

The most frequent method for a multi-technique combination is through co-locating several instruments of different techniques at a subset of sites on Earth. Two space geodetic techniques are operated currently at Yebes observatory, the YEBE GNSS station operated since mid 1990 and the VLBI radio telescopes. The 14-m radio telescope was in use from 1995 to 2004, and the new 40-m radio telescope has participated since 2008 in geo-VLBI sessions (see Figure 1 for a panoramic view of the space geodetic instruments co-located at the Yebes observatory).

Co-location by itself is not enough for the combination. The actual geometric three-dimensional local vector tying the physical reference points of each instrument must be accurately known. This three-dimensional vector is known as the local tie. In the ITRF combination, the available local ties are used as additional observations with their proper variances together with the TRF solutions provided by each technique. The determination of the local ties is usually carried out by highly precise local terrestrial surveys. Currently, the method to determine the local tie between the 40-m VLBI radio telescope and the YEBE GNSS station at the Yebes observatory is under study. First, the Invariant Reference Point (IRP) of the 40-m radio telescope needs to be estimated [4]. Please refer to Santamaría-Gómez et al. and their work in this IVS 2012 General Meeting Proceedings volume for further information [3].

As a preliminary assessment of the local-tie survey, the estimation of the position and velocity in the ITRF2008 of the reference points of the different instruments is used to derive the relative vector between them at the Yebes observatory.

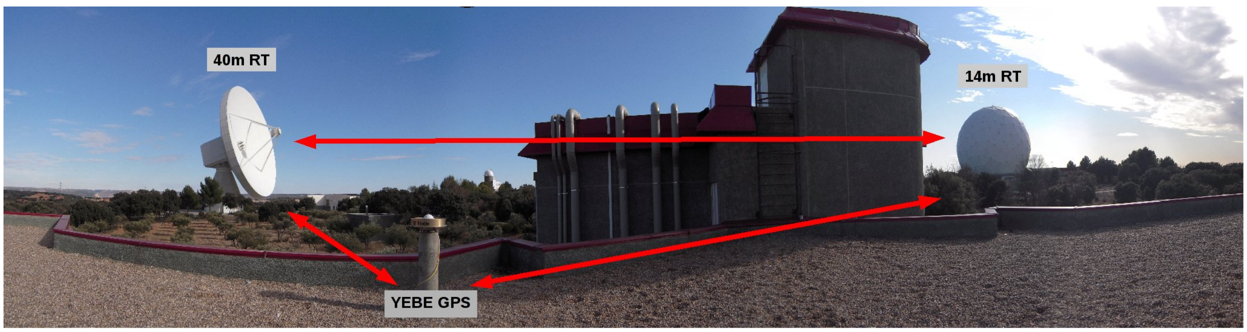

Figure 1. GPS antenna and VLBI radio telescopes at Yebes Observatory.

2. Estimation of the Local Relative Vectors

The coordinates of the 40-m radio telescope were estimated in the ITRF2008. Daily VLBI terrestrial frames, in Solution Independent Exchange (SINEX) format from the Goddard IVS Analysis Center (GSFC), were stacked in order to estimate the long-term position and velocity of the 40-m radio telescope. Only the SINEX files in which the 40-m Yebes radio telescope was included were stacked using the CATREF software [1]. Each input daily terrestrial frame (radio telescope positions) was aligned through a seven-parameter similarity transformation into a long-term (radio telescope positions and velocities) mean terrestrial frame while applying internal constraints on the transformation parameters. The resulting position time series for each radio telescope were checked and corrected for outliers and offsets, mainly due to earthquakes. Finally, the long-term terrestrial frame was aligned to the ITRF2008. A 14-parameter similarity transformation was applied with minimal constraints using the high-quality coordinates and velocities of a set of 20 radio telescopes extracted from the ITRF2008.

From 12 July 2011 onwards, the subreflector of the 40-m radio telescope was fixed to its optimum position for an elevation of 45° for geodetic VLBI sessions. A position offset was therefore included in the time series, and the radio telescope coordinates were estimated before and after the discontinuity. The radio telescope velocity was constrained between both segments. After the change of the focus, a significant offset of ∼4.6cm was found in the vertical coordinate (see Figure 2 top right).

The coordinates for the YEBE GPS station and the 14-m radio telescope were extracted from the ITRF2008. With the coordinates of all the instruments in a common terrestrial frame (ITRF2008) and at a common epoch (2010.4), the local relative vectors between the space geodetic instruments were estimated straightforwardly (see Table 1).

Table 1. Estimated local relative vectors (m) in ITRF2008 at epoch 2010.4 between the space geodetic instruments at the Yebes observatory.

	ΔX	ΔY	ΔZ	$\sigma\Delta$X	$\sigma\Delta$Y	$\sigma\Delta$Z	σ3D
14m-40m	18.2822	-217.5799	-49.1285	0.0064	0.0025	0.0055	0.0088
40m-YEBE	37.2256	147.8632	-9.1818	0.0023	0.0010	0.0019	0.0031
YEBE-14m	-55.5078	69.7167	58.3104	0.0064	0.0025	0.0055	0.0085

3. Discussion

The precision in the estimation of the relative positions between these different instruments depends directly on the precision of each space geodetic technique and also on the data available for each instrument. Thus, the relative vectors including the 14-m radio telescope are excessively loose due to the fact that this radio telescope was decommissioned in 2004, and the uncertainty of its estimated position in epoch 2010.4 is heavily affected by the data scatter (see Figure 2 top left). A local-tie survey of this radio telescope today would therefore provide little constraint for the ITRF combination.

The estimated precision for the 40-m YEBE relative vector is reduced to 3 mm, which however, is still far from the demanded sub-mm level accuracy in the frame of the GGOS initiative [2]. In order to avoid internal distortions of the combined ITRF, the local-tie surveys should be more accurate than the individual space geodesy TRFs used in the combination. This way, regardless of the origin of this uncertainty, the future local-tie surveys at the Yebes observatory will provide a useful constraint for the ITRF combination if it is merely better than 3 mm, despite the demanded sub-mm accuracy. These 3 mm come mostly from the uncertainty of the estimated position of the 40-m radio telescope in the ITRF2008. Although the precision of the 40-m reference point coordinates will improve in the future with more observations, the uncertainty may still be too large unless the scatter of the residuals in the position time series is understood and reduced (see Figure 2 top right).

The scatter of the VLBI residuals shown in Figure 2 may be related to some remaining unmodelled systematic errors (e.g., the radio telescope deformations). If this scatter actually reflects, or at least partially reflects, motion of the IRP of the radio telescopes, a proper local-tie survey methodology should be used for the detection and monitoring of these deformations [3]. On the other hand, the scatter may also reflect technique-dependent systematic deviations of the estimated IRP coordinates in the VLBI data analysis and not real IRP motion. As a matter of fact, the estimated vertical coordinate of the 40-m IRP was shifted by 4.6 cm after changing the observation setup by fixing the focus to its optimum position for an elevation of 45°. Yet its relative position with respect to other instruments is not expected to change in-site. This VLBI-dependent effect, which may be being reproduced in other radio telescopes, has therefore a direct impact when tying VLBI and other terrestrial frames.

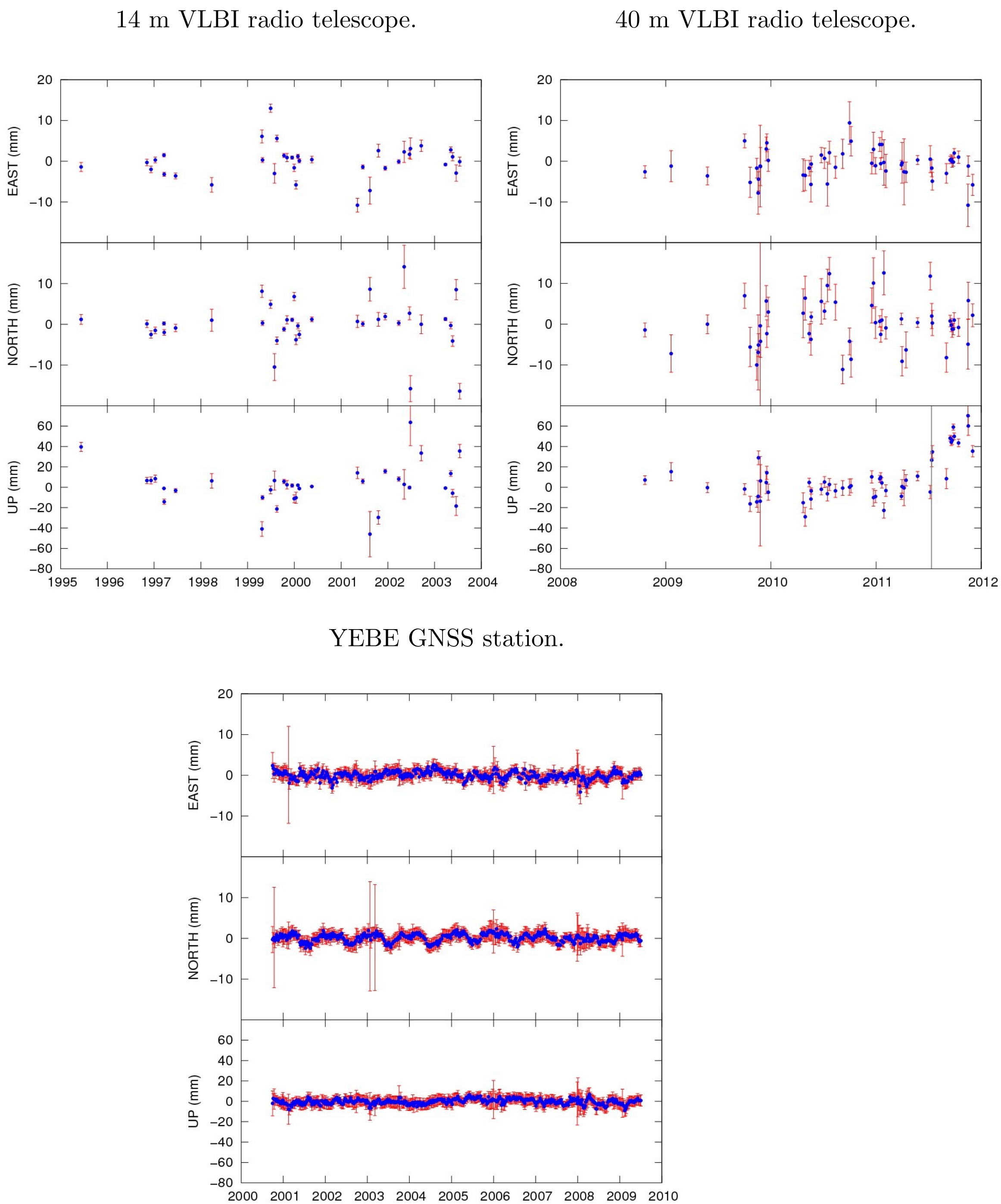

Figure 2. Residual coordinate time series (mean position with velocity removed) of the space geodetic instruments at the Yebes observatory.

References

[1] Altamimi, Z., X. Collilieux, L. Métivier, ITRF2008: an improved solution of the international terrestrial reference frame, J. Geod. 85, 457-473, doi:10.1007/s00190-011-0444-4, 2011.

[2] Gross, R., G. Beutler, H.-P. Plag, Integrated scientific and societal user requirements and functional specifications for the GGOS. In: Global Geodetic Observing System, edited by H.-P. Plag and M. Pearlman, 2009.

[3] Santamaría-Gómez, A., S. Garcia-Espada, R. Haas, Estimation of the invariant reference point: first steps at Yebes. In: IVS 2012 General Meeting Proceedings, edited by D. Behrend and K. D. Baver, This volume.

[4] Santamaría-Gómez, A., S. Garcia-Espada, Simulating the estimation of the 40 m radio telescope Invariant Reference Point at the Yebes observatory In: Yebes Observatory Technical Report IT-OAN 2011-9.